NSPE NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS

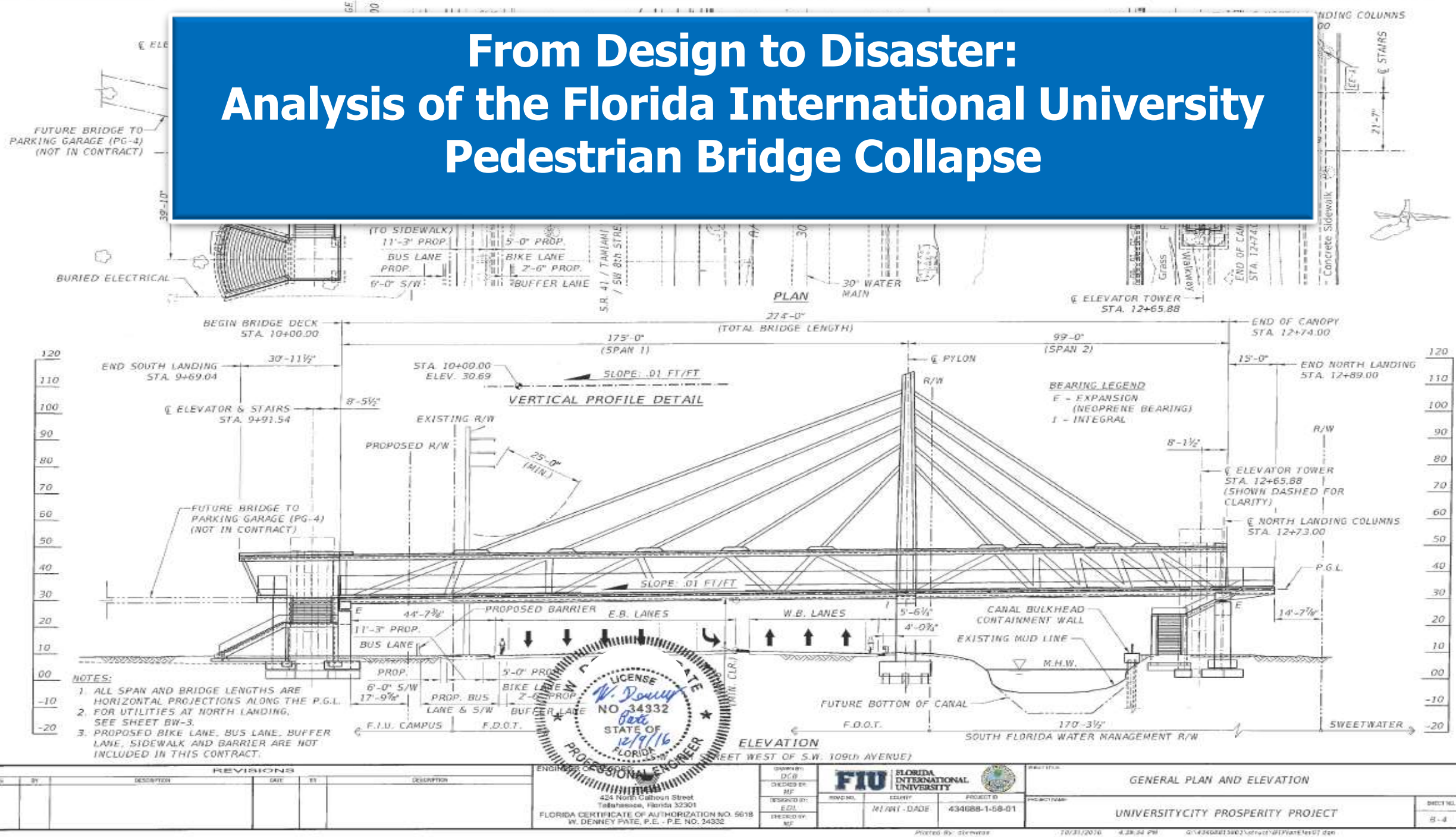
2020 Virtual PROFESSIONAL ENGINEERS CONFERENCE

AUGUST 3–7, 2020

Robert Sumwalt

The role and responsibility of professional engineers in ensuring safety of our Nation's infrastructure

From Design to Disaster: Analysis of the Florida International University Pedestrian Bridge Collapse




Michael Graham


Bruce Landsberg

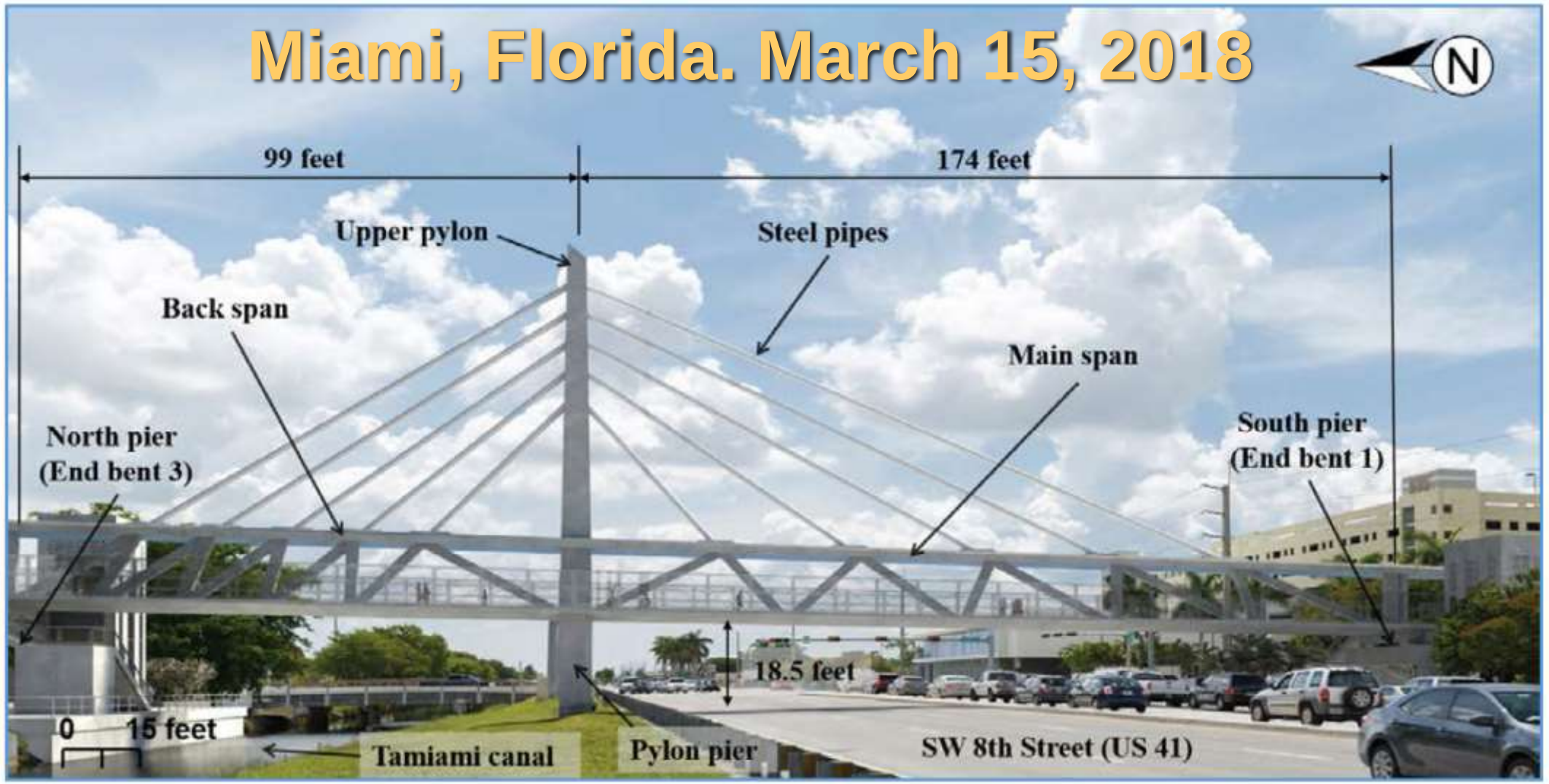

Robert Sumwalt


Jennifer Homendy


Thomas Chapman

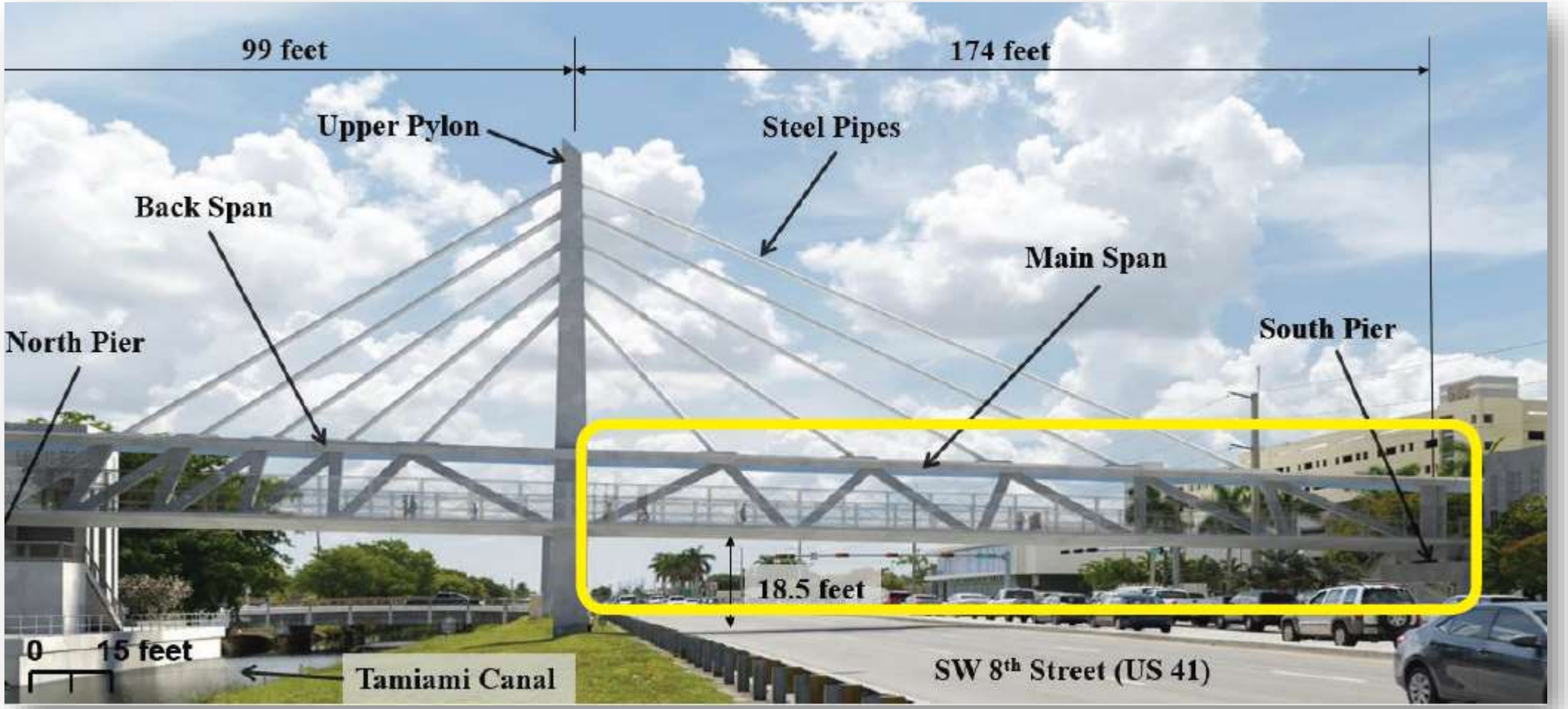

NTSB


09 13
10 13
11 13
12 14
1 14
17 14

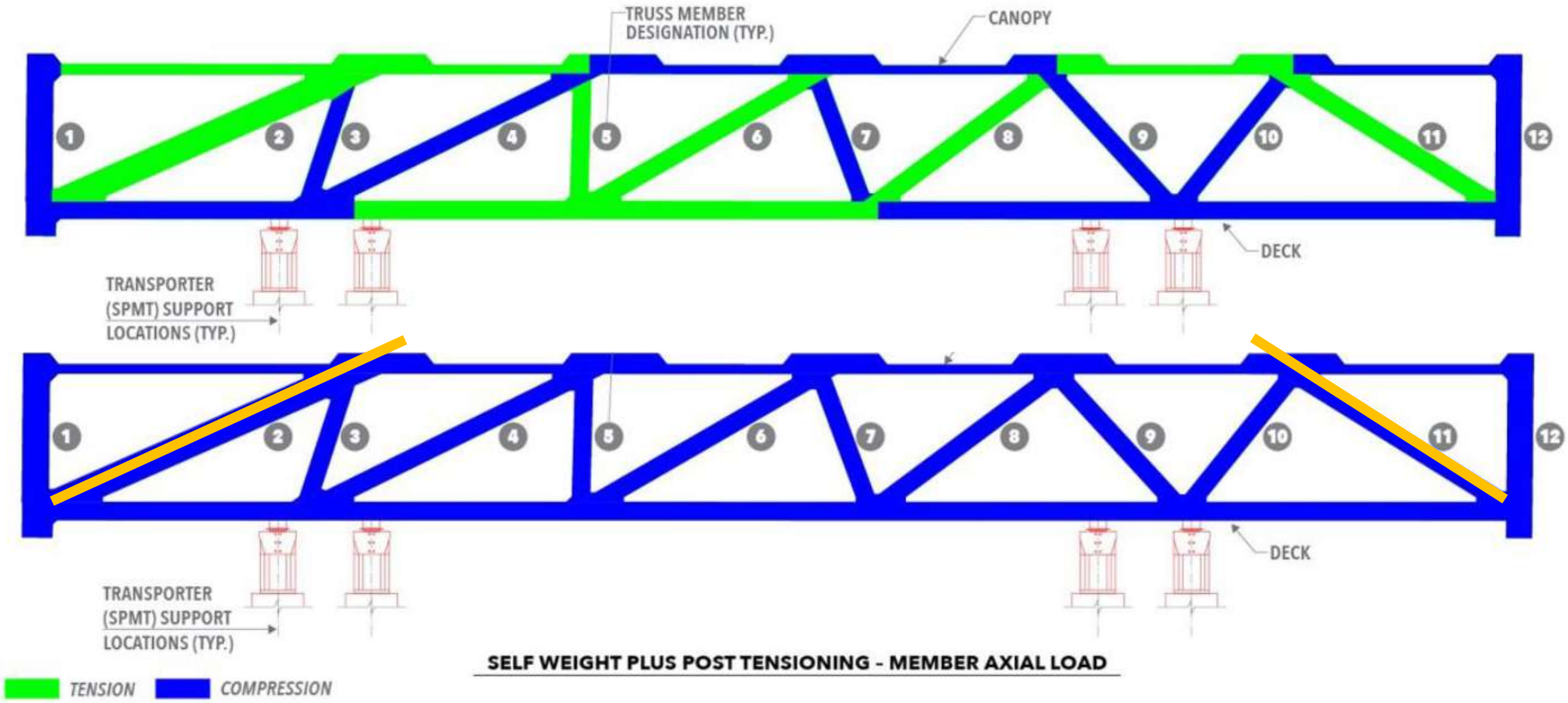

Miami, Florida. March 15, 2018
N
99 feet
174 feet
Upper pylon
Steel pipes
Back span
Main span
North pier
(End bent 3)
South pier
(End bent 1)
18.5 feet
0
15 feet
Tamiami canal
Pylon pier
SW 8th Street (US 41)


Upper pylon
Steel pipes
Canopy
North elevator
South elevator
SW 8th Street (US 41)
Grand staircase
Not to scale

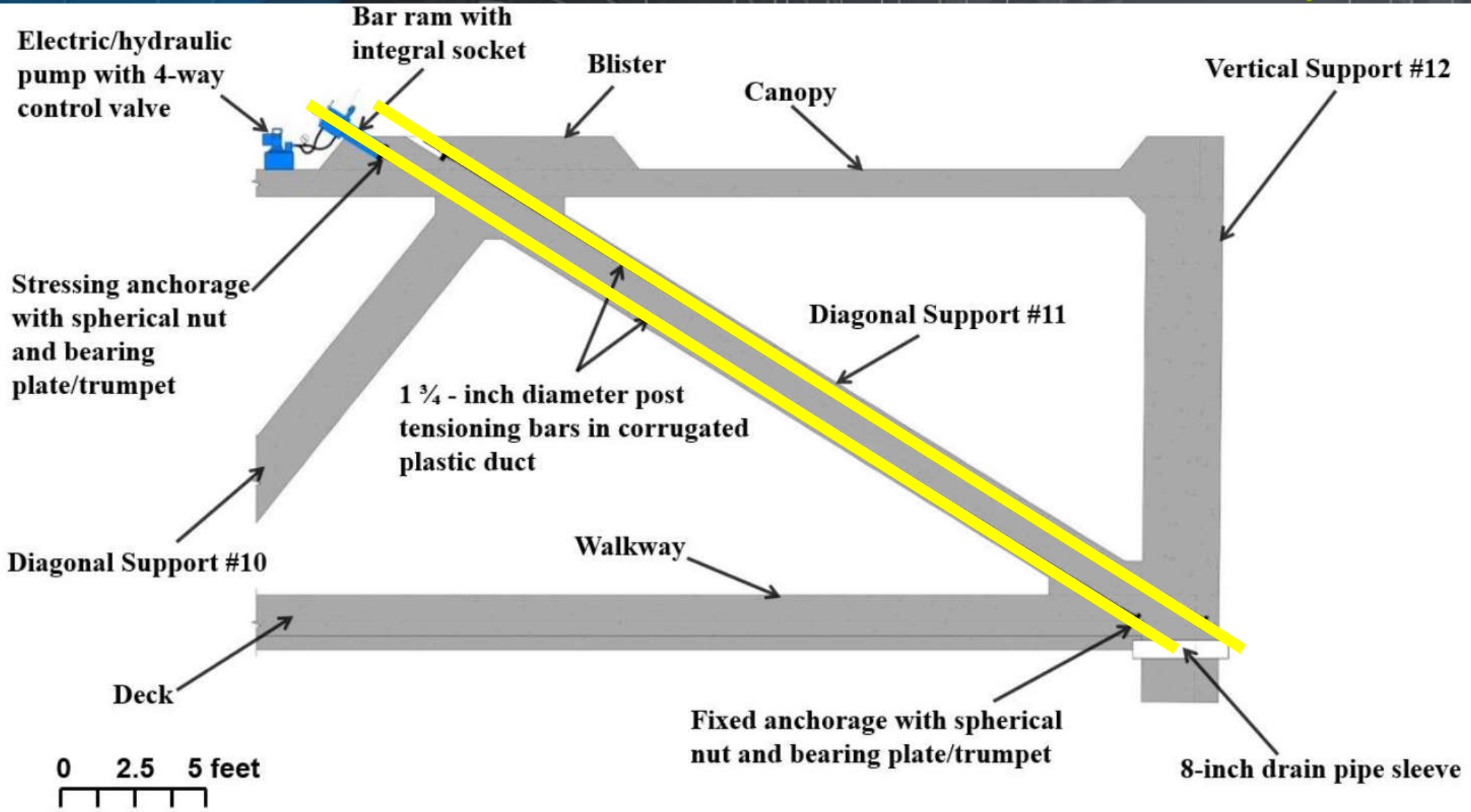

Canopy
Diagonal Supports
Walkway


99 feet
174 feet
Upper Pylon
Steel Pipes
Back Span
Main Span
North Pier
South Pier
18.5 feet
0 15 feet
Tamiami Canal
SW 8th Street (US 41)

Accelerated Bridge Construction



SELF WEIGHT PLUS POST TENSIONING - MEMBER AXIAL LOAD


Electric/hydraulic pump with 4-way control valve
Bar ram with integral socket
Blister
Canopy
Vertical Support #12
Stressing anchorage with spherical nut and bearing plate/trumpet
Diagonal Support #11
1 ¾ - inch diameter post tensioning bars in corrugated plastic duct
Diagonal Support #10
Walkway
Deck
Fixed anchorage with spherical nut and bearing plate/trumpet
8-inch drain pipe sleeve
0 2.5 5 feet

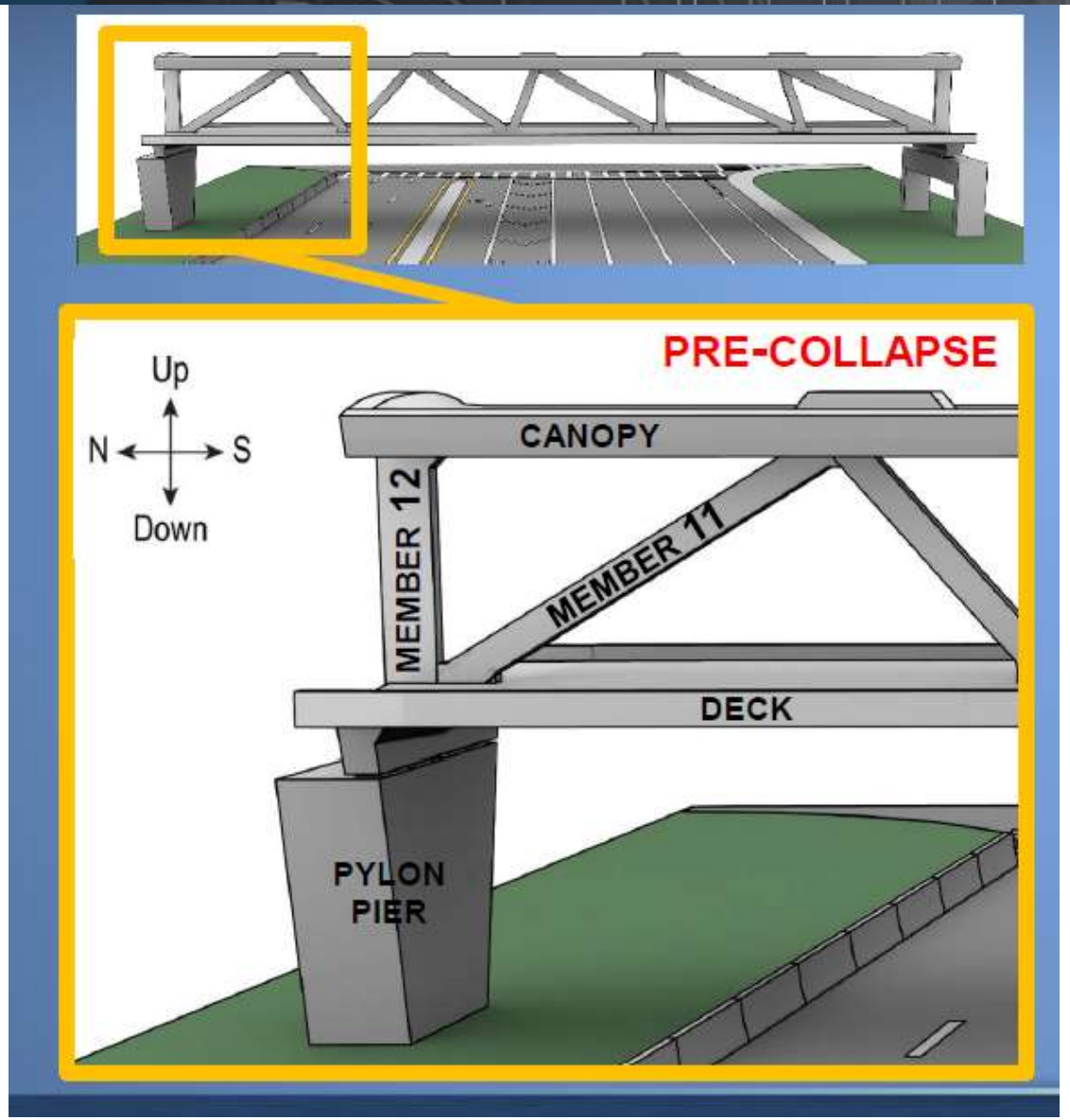
March 10, 2018

March 15, 2018


Canopy fracture and hinge area
12
11
10
9
8
7
6
5
4
3
2
1
Deck fracture area


N
Member 12
Intact members
4
3
2


N
Concrete blowout
12
11
SW 8th Street

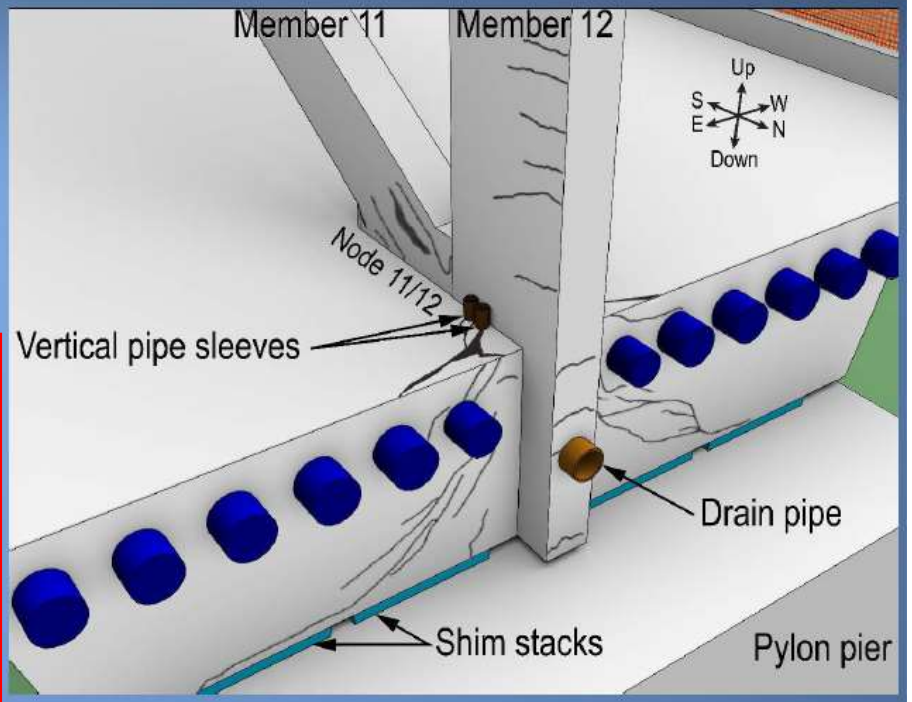

PRE-COLLAPSE
Up
N
S
Down
CANOPY
MEMBER 12
MEMBER 11
DECK
PYLON
PIER

- **Concrete** - Tested compressive strength and tensile behavior.
- **Steel PT bars and rebar** – tested yield and tensile strength, and percent elongation.
  - Analyzed chemical composition of PT rods.

All material specimens were within specifications.

Cracking in Member 11/12 Nodal Region

- Structure showed notable cracking of reinforced concrete
- Extensive and large cracks in member 11/12 should have been recognized as abnormal
  - Cracks up to 0.016 inch wide – considered acceptable
  - Structural cracks in bridge were up to 0.75 inch wide – 40 times larger than typically acceptable
- Scale of cracking clear indication that load- resisting mechanisms were failing

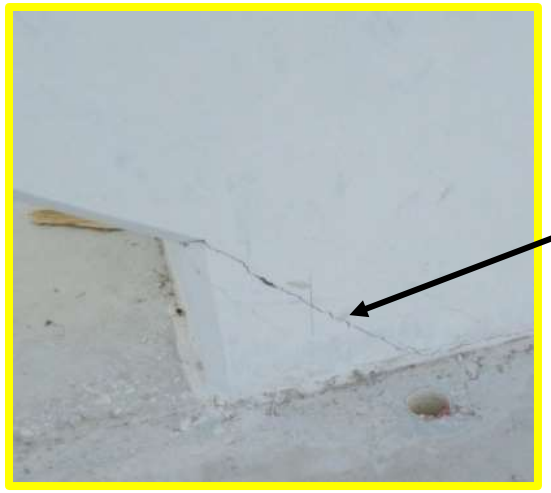



Vertical
Member 12
Diagonal Member 11

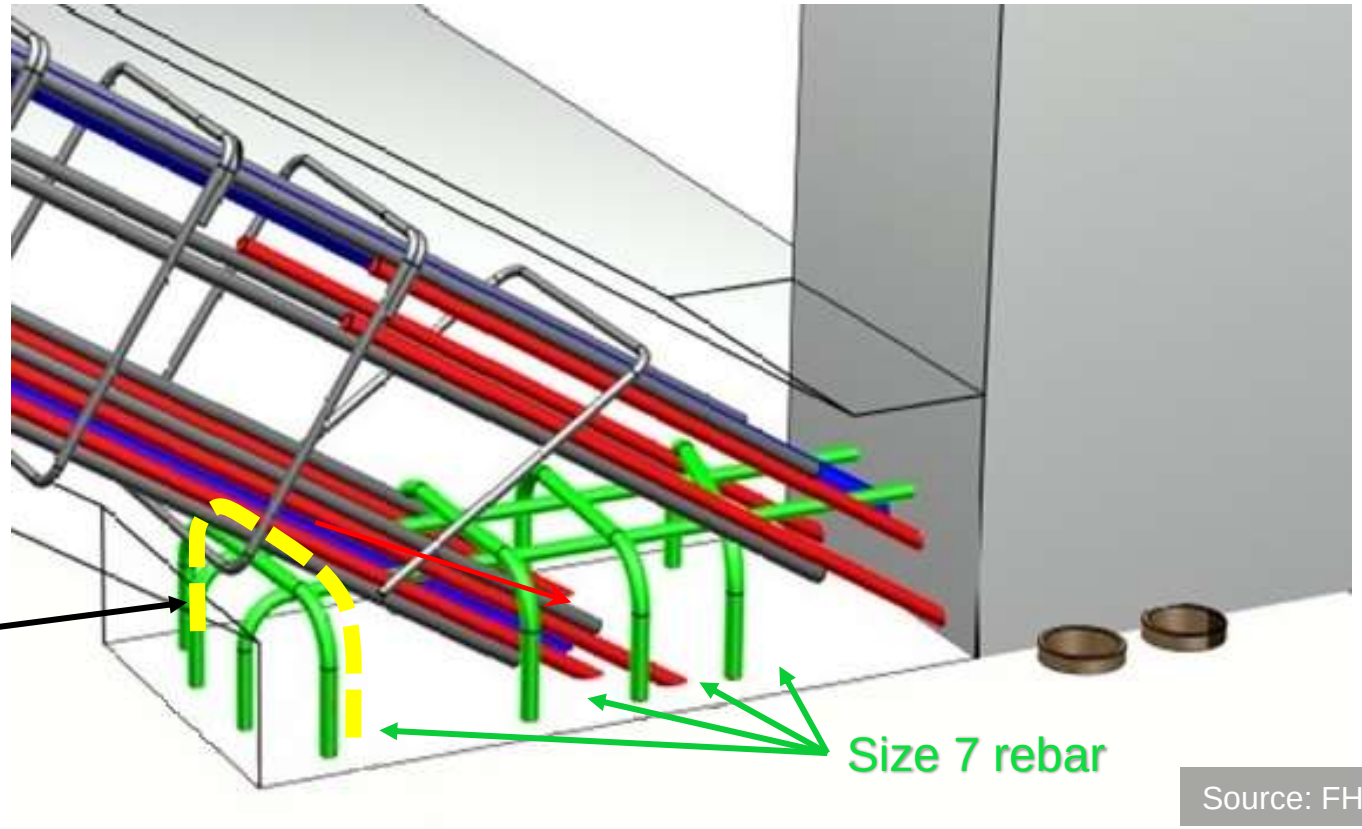

Diagonal Member 11
Deck

First Signs of Structural Distress

- Portion of crack bypassed 25% of reinforcing steel at base of member 11



Crack passed above the southernmost two size 7 rebars



Source: FHWA

Date	Time	Communication Method	Response
March 13	9:45 a.m.	Email from FIGG design manager to MCM	"We do not see this as a safety issue"
--	4:13 p.m.	Voice mail message from FIGG EOR to FDOT	"But from a safety perspective, we don't see that there's any issue there, so we're not concerned about it from that perspective"
--	5:18:22 p.m.	Email from FIGG design manager to MCM	"Again, we have evaluated this further and confirmed that this is not a safety issue"
March 14	10:50 a.m.	Email from MCM to Structural Technologies	"FIGG has further evaluated and confirmed that the cracks encountered on the diaphragm do not pose a safety issue and/or concern"
March 15	9:00 a.m.	Presentation by FIGG EOR at meeting with FDOT; FIU; MCM; Bolton, Perez (and others)	"And, therefore, there is no safety concern relative to the observed cracks and minor spalls"
--	--	Meeting minutes prepared by Bolton, Perez	"FIGG assured that there was no concern with safety of the span suspended over the road"
--	--	Meeting minutes of March 15 prepared by FIGG	"Based on the discussions at the meeting, no one expressed concern with safety of the span suspended over the road"

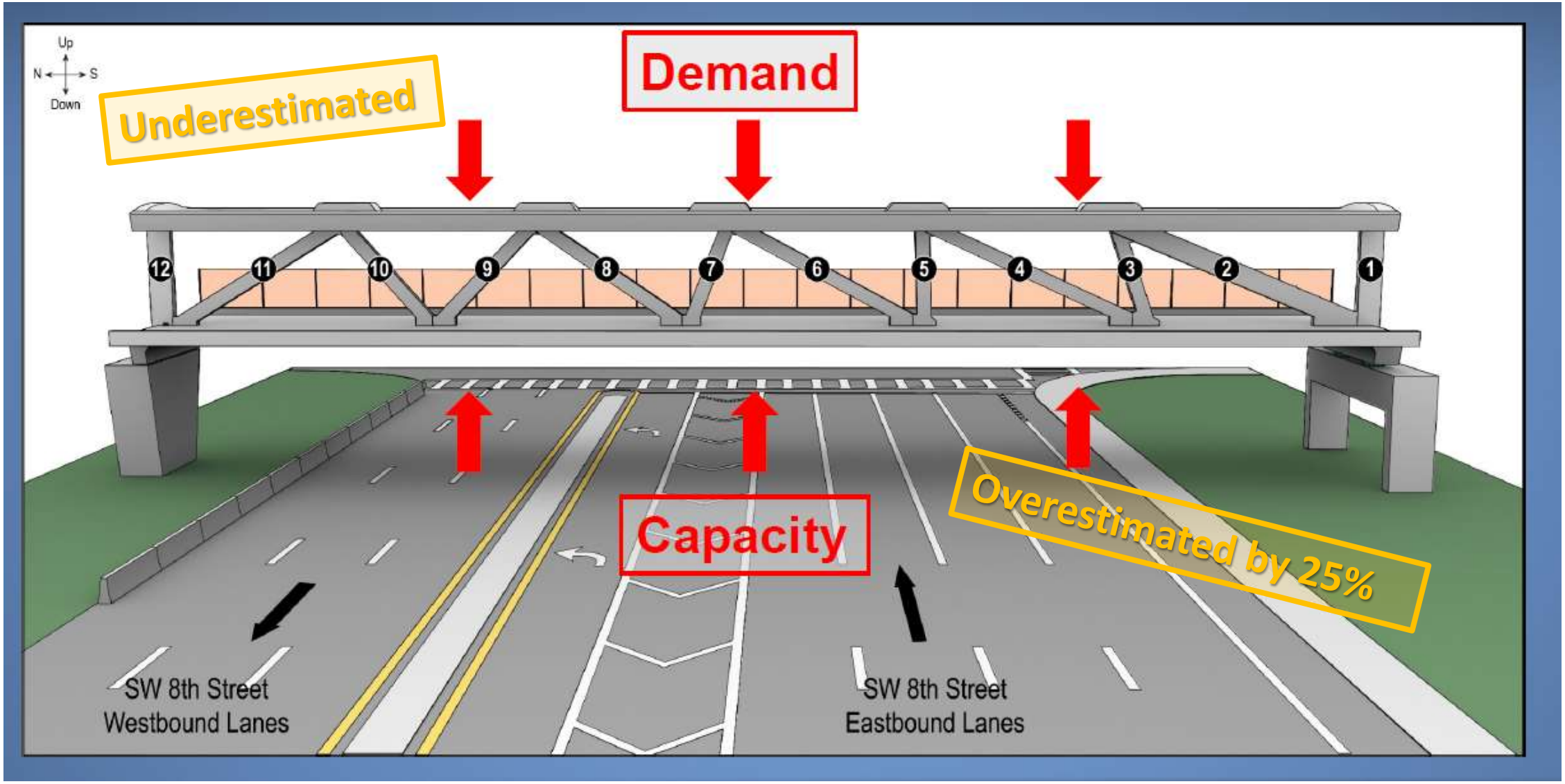
Conclusion

- Based on conservative calculations, it is concluded that the design meets LRFD strength requirements for this temporary condition …
- And therefore the is no safety concern relative to the observed cracks and minor spalls

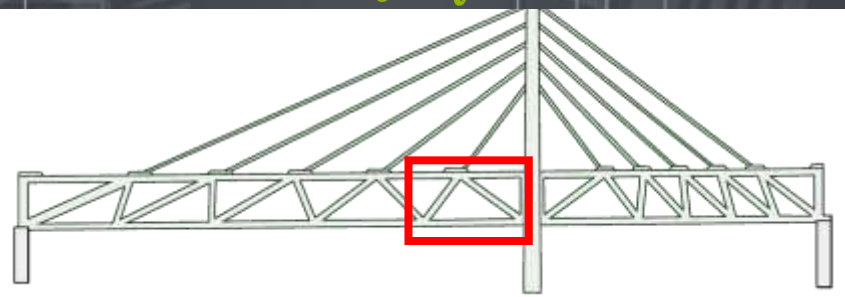

MIAMI
10:10 AM ET
FOX NEWS LIVE
NTSB CHAIR: NTSB HAS BROUGHT A FULL INVESTIGATIVE TEAM
FOX NEWS ALERT

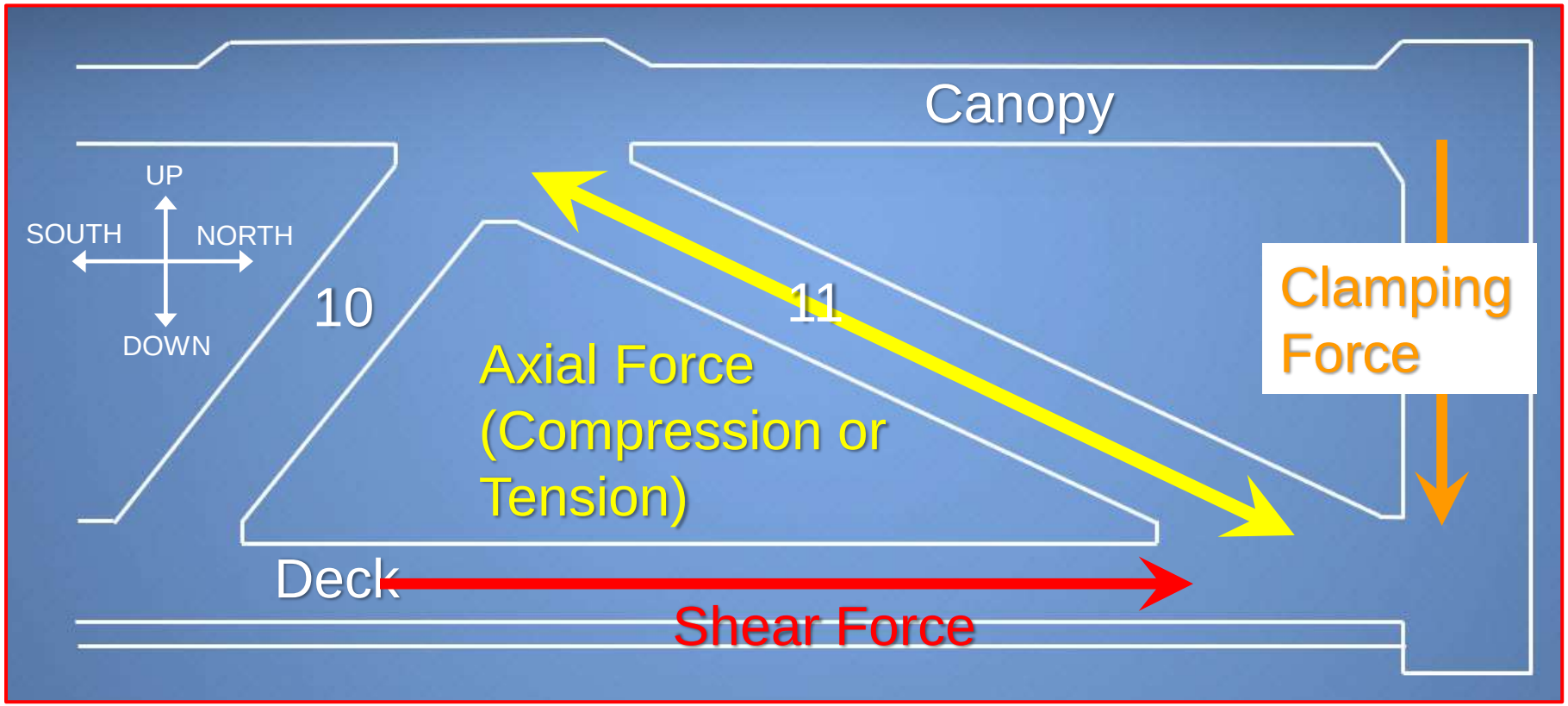
Critical Errors

- Bridge was under-designed
- Peer review was insufficient
- Failure to close bridge to traffic and workers


Up
N
S
Down
Underestimated
Demand
12
11
10
9
8
7
6
5
4
3
2
1
Capacity
Overestimated by 25%
SW 8th Street
Westbound Lanes
SW 8th Street
Eastbound Lanes

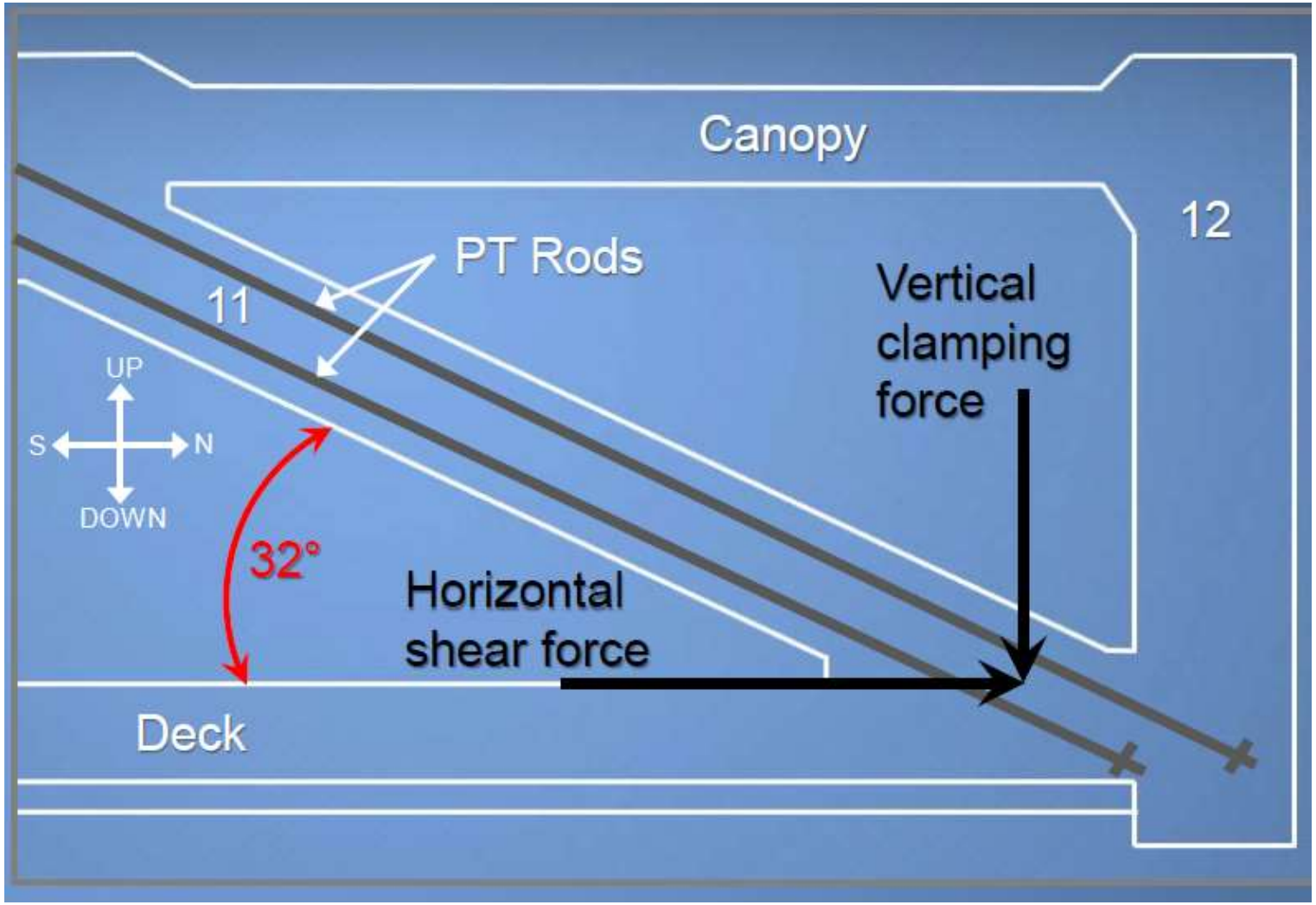
Forces on 11/12 nodal region





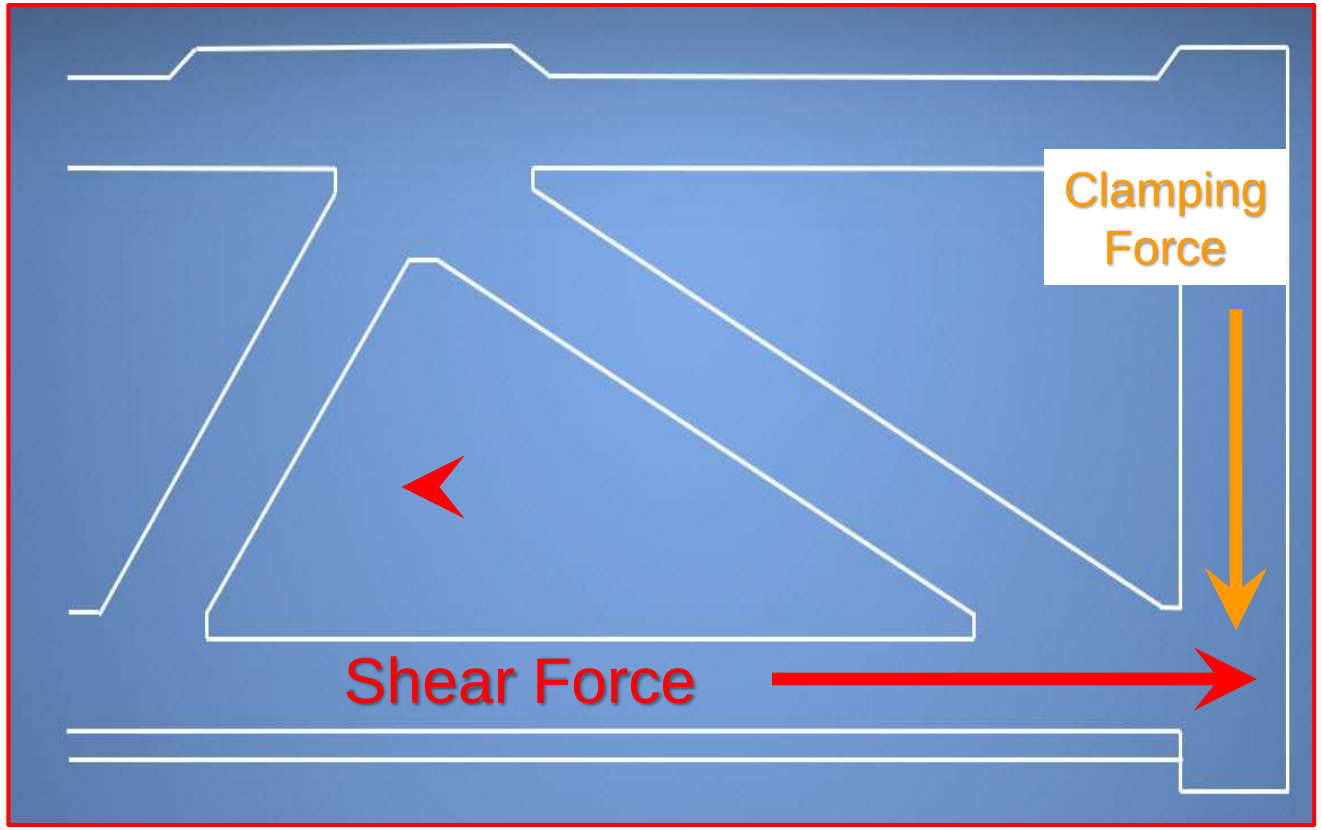
Magnitude of horizonal force –

60 percent larger than vertical force

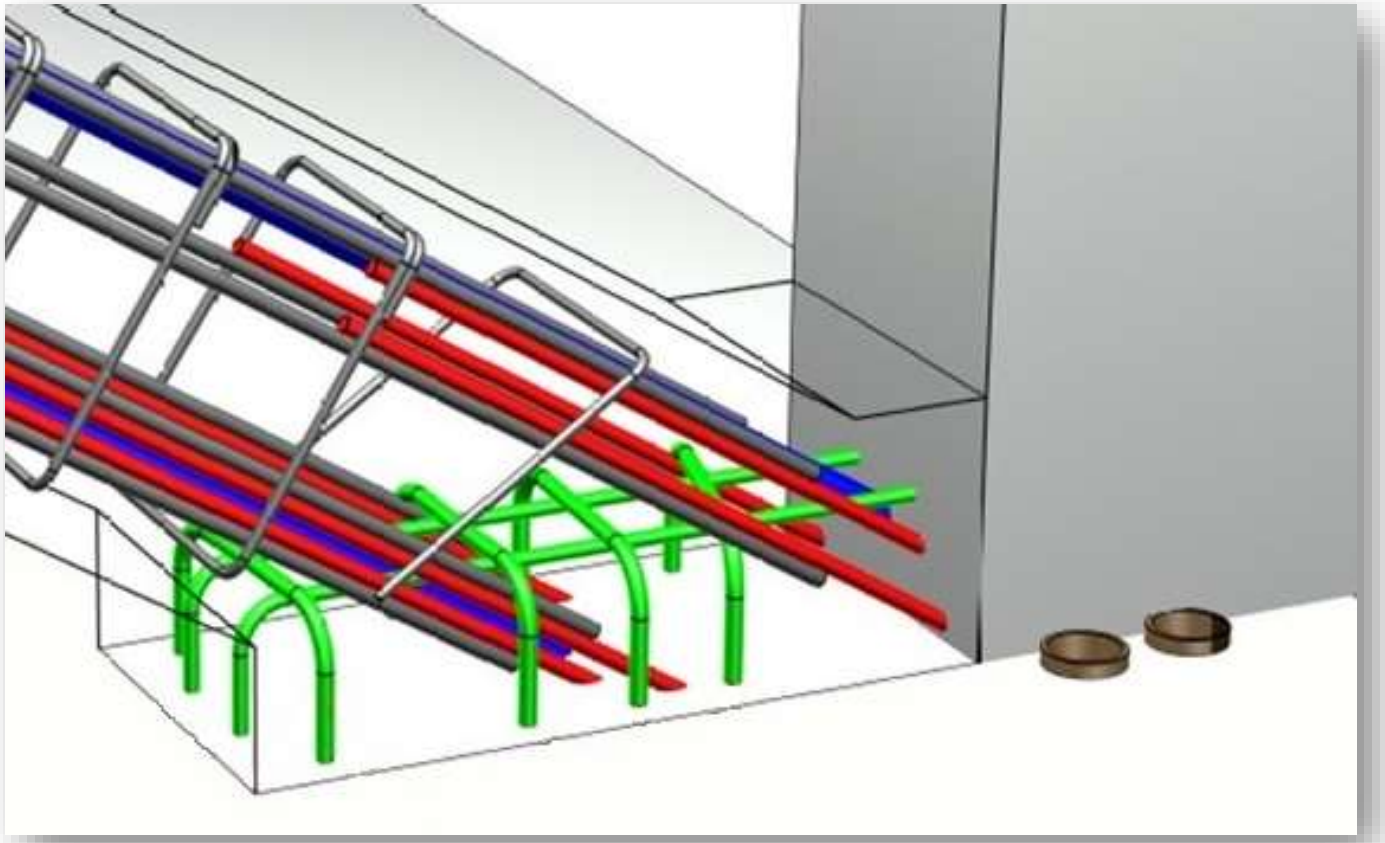


Interface Shear Demand

Figg underestimated interface shear demand at nodal region 11/12 by 46%.



270 percent more rebar needed



- Member 11 needed **18** square inches cross sectional area of rebar.
- It only had 4.8 square inches.

Summary

- FIGG design made significant errors in determining loads
- Chose the wrong interface shear demand value
  - Led to severe underestimation of demand
- Chose the wrong load factor in calculating the permanent compression loading (P_c)
- Led to a significant overestimation of capacity

The National Transportation Safety Board (NTSB) determines that the probable cause of the Florida International University (FIU) pedestrian bridge collapse was the load and capacity calculation errors made by FIGG Bridge Engineers, Inc., (FIGG) in its design of the main span truss member 11/12 nodal region and connection to the bridge deck. Contributing to the collapse was the inadequate peer review performed by Louis Berger, which failed to detect the calculation errors in the bridge design. Further contributing to the collapse was the failure of the FIGG engineer of record to identify the significance of the structural cracking observed in this node before the collapse and to obtain an independent peer review of the remedial plan to address the cracking. Contributing to the severity of the collapse outcome was the failure of MCM; FIGG; Bolton, Perez and Associates Consulting Engineers; FIU; and the Florida Department of Transportation to cease bridge work when the structure cracking reached unacceptable levels and to take appropriate action to close SW 8th Street as necessary to protect public safety.

40 YEARS in 2018

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6 Nations

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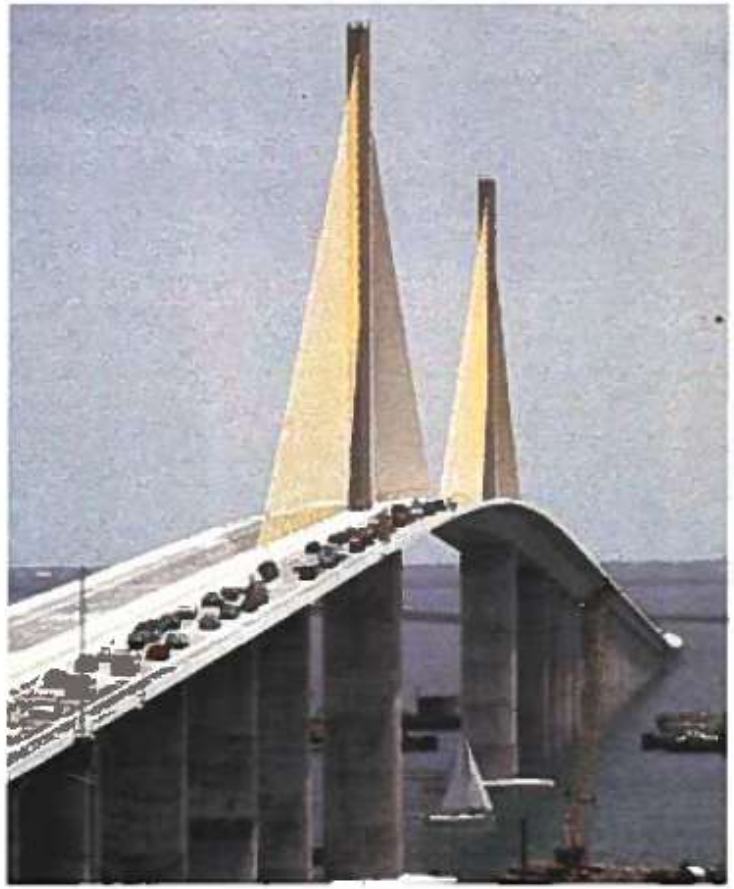
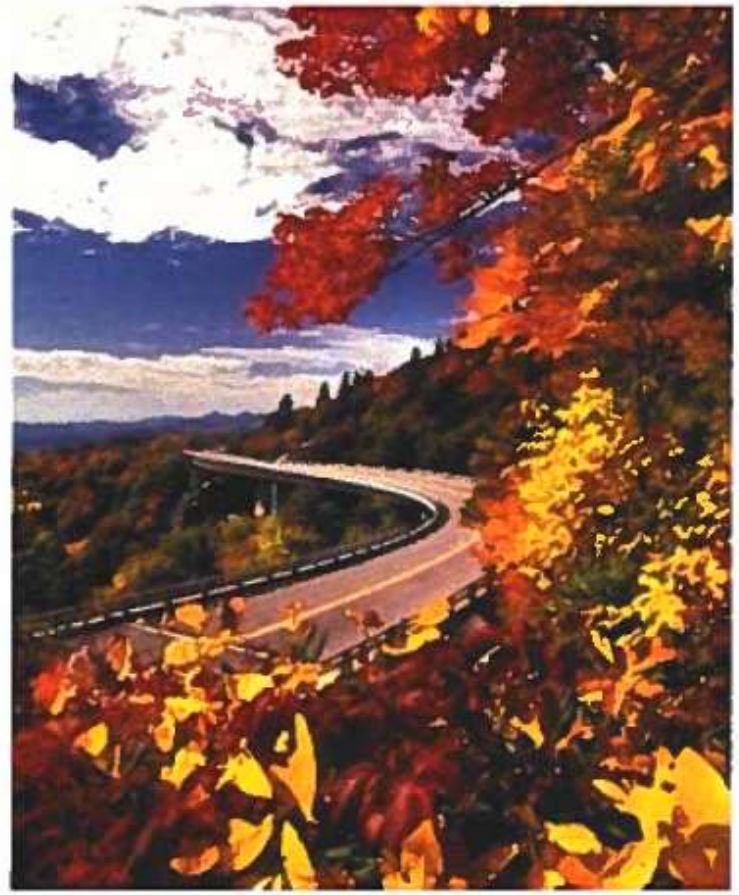


Sunshine Skyway Bridge, FL



Blue Ridge Parkway Viaduct, NC
National Park Service

Natchez Trace Parkway Arches, TN
National Park Service

3 Presidential Awards

through the National Endowment for the Arts
-US Presidents gave 5 of these awards for Bridges-

FIGG

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FIGG Has Delivered More Concrete Cable-Stayed Bridges than any Firm in America

14 built concrete cable-stays in U.S.

12 FIGG responsible charge

7 Engineer of Record -
A first for each state

5 Precast concrete -
Engineer of Record For All of them

BRIEF

TxDOT seeks removal of FIGG from $800M Harbor Bridge design

Designer FIGG Removed From One Bridge Job, Faces Scrutiny on Second

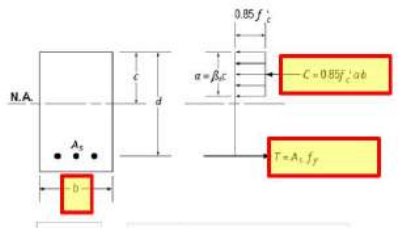
FIGG Presentation on Day of Collapse

Conventional Method

Rectangular Beam Analysis

Data:
- Section dimensions – b, h, d, (span)
- Steel area - As
- Material properties – f'c, fy

Required:
- Nominal Strength (of beam) Moment - Mn
- Required (by load) Design Moment – Mu
- Load capacity



$$c = \frac{a}{\beta_1} \qquad \varepsilon_t = \frac{d-c}{c}0.003 \geq 0.005$$

$$a = \frac{A_s f_y}{0.85 f'_c b} \qquad M_n = A_s f_y\left(d - \frac{a}{2}\right)$$

$$\phi M_n \geq M_u$$

ntrolled)

≥ Mu

Total Nodal Shear Stability

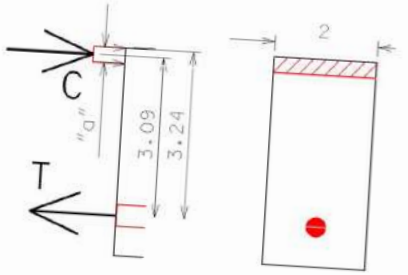
$$V_{ni} = cA_{cv} + \mu\left(A_{vf} f_y + P_c\right)$$

- c x Acv 57.6 k/sf x 23.62 sf = 1360 kips
- Mu x As Fy = 1.4x22.72x60 = 1908 kips
- Mu x Pc = 1.4 x 520 kips = 730 kips
- = 3947 kips Total = Vni
- FIGG's general preference is to neglect the Cohesion portion when practical. Thus, Vni without "C" = 2638 kips
- Phi = 0.9
- Phi)(Vni) = 3552 kips with "c"
- (Phi)(Vni) = 2374 kips without "c"

Conclusions and Recommendations

- The diagonal type cracks, in excess of FDOT criteria, should be sealed with approved methods and materials (Epoxy injection, etc.)
- The spalled areas have not been replicated by the engineering analyses. However …
- The spalled areas are minor and it is recommended that they be prepared using normal procedures and poured back along with the up coming "pylon diaphragm" pour (different from and prior to the falsework pours)

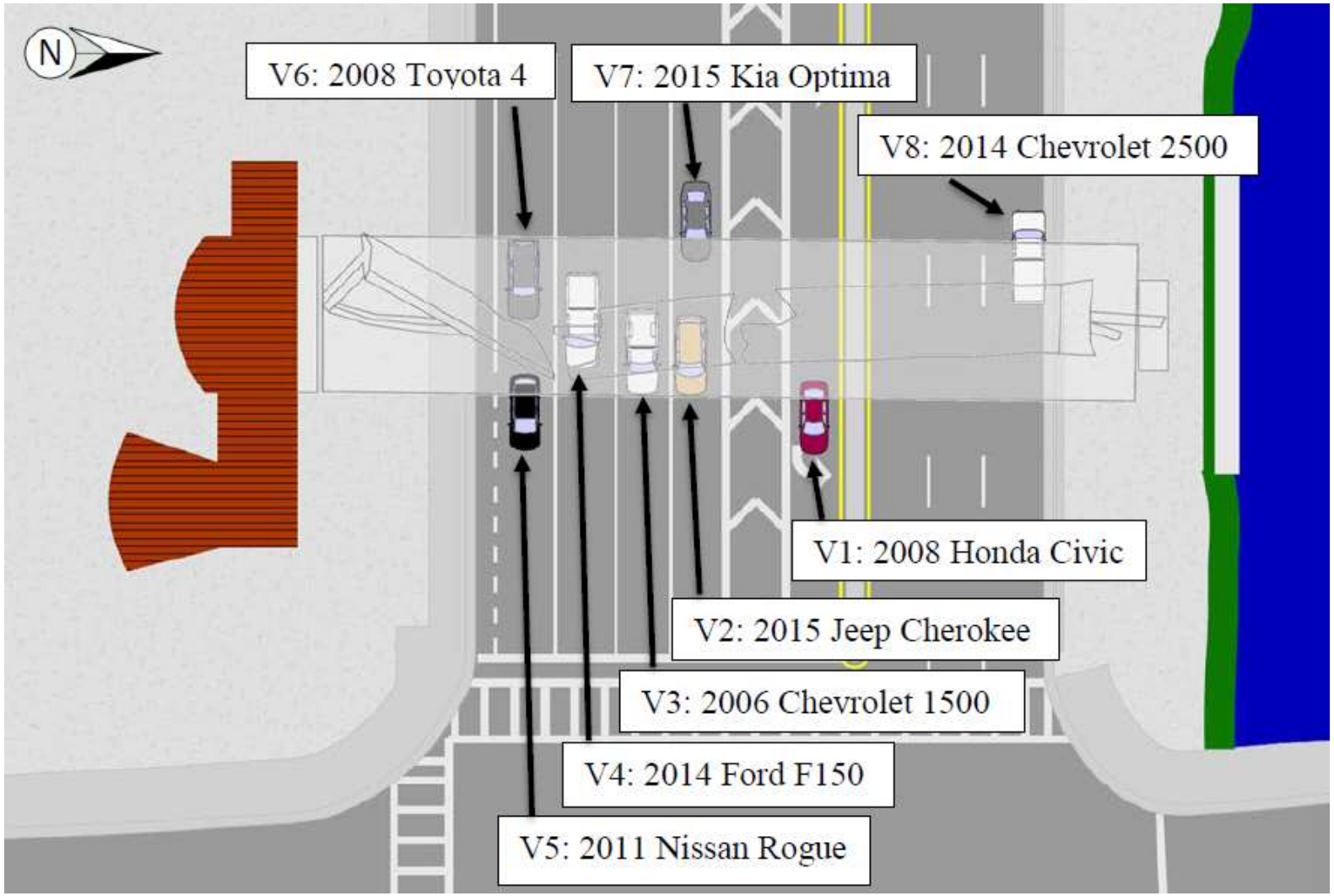
Bending Check – Beam Theory

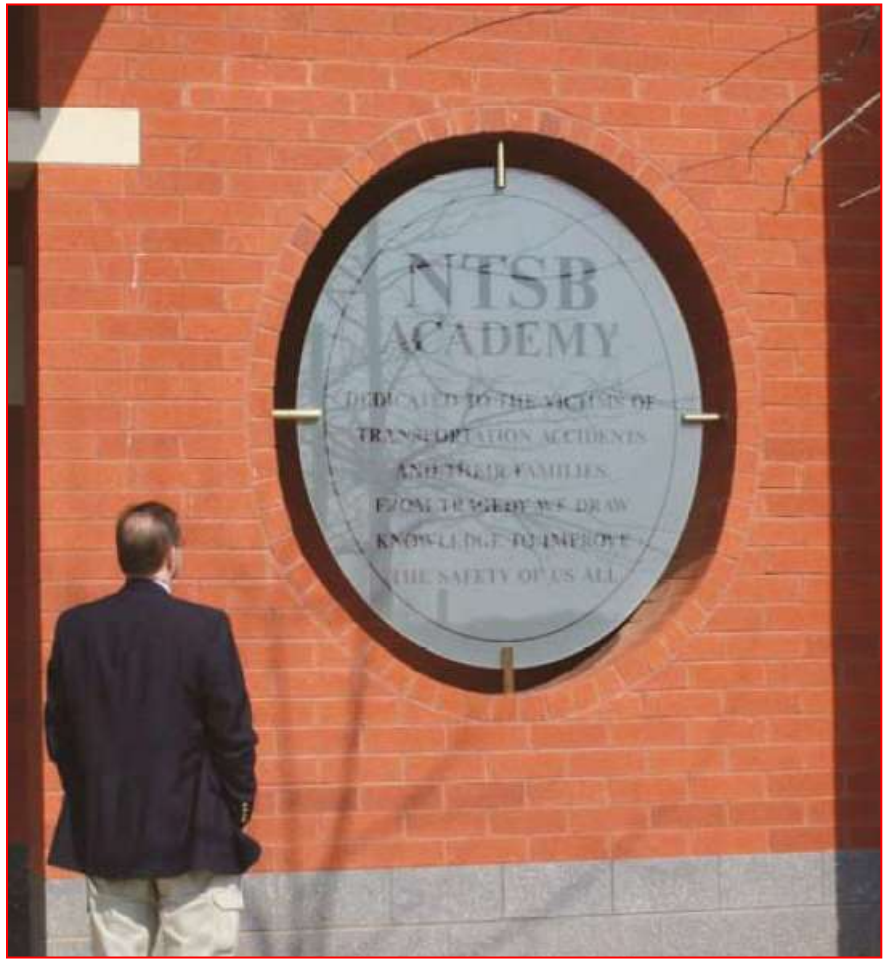


- Steel Area = 13.1 in^2
- T = (13.1)(60 ksi) = 786 kips
- f'c = 8.5 ksi = 1224 ksf
- (a)(.85 f'c)(b) = C = 786 kips
- Solving, "a" = 0.38 ft
- Mn = (T)(d –(a/2)) = 786x3.09'
  = 2398 kip-ft (nominal capacity)
- Phi = 0.9, so (Phi)(Mn) = 2158 kip-ft
- Which is larger than Mu = 2015 kip-ft
- Check OK

Conclusion

- Based on conservative calculations, it is concluded that the design meets LRFD strength requirements for this temporary condition …
- And therefore the is no safety concern relative to the observed cracks and minor spalls


N
V6: 2008 Toyota 4
V7: 2015 Kia Optima
V8: 2014 Chevrolet 2500
V1: 2008 Honda Civic
V2: 2015 Jeep Cherokee
V3: 2006 Chevrolet 1500
V4: 2014 Ford F150
V5: 2011 Nissan Rogue



"From tragedy we draw knowledge to improve the safety of us all."


NATIONAL TRANSPORTATION SAFETY BOARD
E PLURIBUS UNUM